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OPTIMAL RESERVOIR OPERATION FOR IRRIGATION OF CROPS USING GENETIC ALGORITHM: A CASE STUDY OF SUKHI RESERVOIR PROJECT

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ABSTRACT

Genetic Algorithm is one of the global optimization schemes that have gained popularity as a means to attain water resources optimization. It is an optimization technique, based on the principle of natural selection, derived from the theory of evolution, is used for solving optimization problems. In the present study Genetic Algorithm (GA) has been used to develop a policy for optimizing the release of water for the purpose of irrigation. The study area is Sukhi Reservoir project in Gujarat, India. The months taken for the case study are June, July, August and September for three years from year 2004 to 2006. The fitness function used is to minimize the squared difference between the monthly reservoir release and irrigation demand along with squared deviation in mass balance equation. The decision variables are monthly reservoir releases for irrigation and initial storages in reservoir at beginning of the month. The constraints considered for this optimization are the bounds for the reservoir releases and reservoir storage capacity. The results derived by using GA shows that the downstream irrigation demands are completely satisfied and also considerable amount of water is saved.

Keywords: Genetic Algorithm, Optimization, Sukhi Reservoir Project.

I. INTRODUCTION

Genetic Algorithms (GAs) are based on the theory given by Darwin that fittest of the fit will survive. Genetic Algorithms are a family of computational models inspired by evolution. Genetic Algorithms (GAs) have become popular among researchers as a general optimization technique. The results of employment of GAs to a wide variety of problems have indicated their potential in the application to water resource management. The GA technique has been used by K. Srinivasa and D.

Nagesh Kumar [1] to evolve efficient cropping pattern for maximizing benefits for an irrigation project in India. Results obtained by GA are compared with Linear Programming solution and found to be reasonably close. Y.P. Mathur and S.J. Nikam [2] has used GA to optimize the operation of existing multipurpose reservoir in India, and to derive reservoir operating rules for optimal reservoir operations. Results show that, even during the low flow condition the GA model if applied to the Upper Wardha reservoir in Maharashtra State, India, can satisfy downstream irrigation demand. A. B. Dariane and Sh. Momtahen [3] developed the approach to determine optimal reservoir operating policies which is proposed with a real coded genetic algorithm as the optimization method. The parameters of the policies are optimized using the objective values obtained from system simulations. The proposed method has shown to be flexible and robust in optimizing various types of policies, even in models that include nonlinear, nonseparable objective functions and constraints. D. Nagesh Kumar, Ashok Kumar, K. Srinivasa Raju [4] presented Genetic Algorithms (GAs) application in the field of water resources engineering which is of recent origin. Optimal reservoir operation of reservoir for hydropower production involves constrained nonlinear optimization. Hydropower production from the system is maximized with other demands as constraints. Various steps involved in deriving the optimal operating policy for the reservoir using GA are discussed in the paper. Otto Schmidt and Erich J. Plate [5] have established the relationship between the size of the irrigation area and the operation schedule of a reservoir delivering the irrigation water. The objective for operation of an irrigation system should be the optimum use of all available water in the sense of maximization of the crop production for the whole irrigation area. The solution of this planning problem is obtained by means of a stochastic simulation method. Jiabao Guan, Elcin Kentel, and Mustafa M. Aral [6] presented Genetic algorithms (GAs) which have been shown to be an efficient tool for the solution of unconstrained optimization problems. The method that is utilized in the Complex Algorithm to solve constrained optimization problems is abstracted to develop a repairing procedure for GAs. The proposed procedure, which handles infeasible solutions that may be generated in a standard GA process, is embedded into the conventional GA to yield an improved GA process (IGA) for the solution of optimization problems with equality and inequality constrains. Kulvinder Singh and Rakesh Kumar [7] presented the study of optimization of software testing techniques by using Genetic Algorithms (GAs) and specification based testing. Some new categories of genetic codes are applied in some problem optimizations for the generation of reliable software test cases based on the specification of the software. Based on new genetic strategy and GAs symmetric code is developed. O. Gharsallah, I. Nouiri, F.Lebdi and N. Lamaddalena [8] developed the Genetic algorithm (GA) model for computation of the optimal supply hydrographs in on demand irrigation systems aimed at the optimal regulation of the upstream storage reservoirs. The optimal solution guarantees to satisfy the daily demand requirements, to minimize the maximum discharge delivered by the upstream dam, and to avoid the reservoirs emptiness.

In the present study, a GA model has been used for optimum reservoir operation. The objective of this study is to minimize the squared deviation of monthly irrigation demand deficit along with squared deviation of mass balance equation. The decision variables used are the reservoir release for irrigation demand and initial storage in reservoir in each month. The constraints used for this optimization are bounds for the reservoir releases and reservoir capacity.

II. STUDY AREA

The present study is carried out on Sukhi Reservoir and its command area located near village Sagadhra and Khos in Pavijetpur and Chhota-Udepur taluka of Vadodara District Gujarat state. Its catchment area of 25.90 sq. km. in Madhya Pradesh and 385.91 sq. km. in Gujarat, thus having a Total Catchment area of 411.81 sq. km. Total irrigation benefit to 17094 ha areas of 92 villages of district Vadodara and 3607 ha areas of 39 villages Panchmahals district by this project.

III. MODEL DEVELOPMENT

In the present study, the fitness function of the GA model is to minimize the squared difference between the monthly reservoir release and irrigation demand along with squared deviation in mass balance equation. The months considered for the study are June, July, August, and September for the year 2004 to 2006 respectively. The objective function is given by equation 1.

$$Z = \text{Minimize} \sum_{t=1}^{12} (R_t - D_t)^2$$

Where,

R_t = Monthly irrigation release for the month t.

D_t = Monthly downstream irrigation demand for the month t.

The above fitness function of GA model is subjected to the following constraints and bounds,

A. Irrigation Demand Constraints

The releases of water for irrigation should be less than the maximum demand for irrigation.

$$R_t < D_{t\,max} \qquad t = 1, 2, 3, 4$$

Releases in each month should be greater than or equal to the minimum irrigation demand.

$$R_t \geq D_{t\,min} \qquad t = 1, 2, 3, 4$$

Where,

$D_{t\,max}$ = Maximum irrigation demand in period t.

$D_{t\,min}$ = Minimum irrigation demand in period t.

B. Reservoir storage continuity constraints

$$S_{t+1} = S_t + Q_t - R_t - A_o\,(E_t) \qquad t = 1, 2, 3, 4$$

Where,

S_{t+1} = Final storage at the end of period t.

S_t = Storage at the beginning of the period t.

Q_t = Inflow during the period t.

R_t = Release for irrigation in period t.

A_o = Reservoir water surface area corresponding to the dead storage volume.

E_t = Evaporation rate for the period t.

C. Reservoir storage capacity constraints

The reservoir storage in any period should not exceed its active storage capacity (S_{max}) of the reservoir.

$$S_t \leq S_{max} \qquad t = 1, 2, 3, 4$$
$$S_t \geq S_{min} \qquad t = 1, 2, 3, 4$$

Where,

S_{max} = Active storage capacity of reservoir in MCM.

S_{min} = Dead Storage of the reservoir in MCM.

IV. RESULTS AND DISCUSSION

In the present GA model analysis the important input variables are the monthly reservoir inflow and monthly downstream irrigation demands for the month of June, July, August and September from year 2004 to 2006. After applying GA method to the above model the following results are generated which gives the optimal releases by GA and so that we consider it as optimum reservoir releases for the year 2004 to 2006.

Table 1: Demand, Actual Release and Obtained Release by GA for the year 2004 to 2006

Month	June	July	August	September
Actual Release, MCM	3009.61	2856.12	2163.33	312.84
Release by GA, MCM	2691.36	1536.52	1265.55	462.24
Demand, MCM	2685.23	1529.21	1262.13	460.71

Table 1 shows the values of the actual release, optimum release achieved by genetic algorithm model and the irrigation demand for every month of June, July, August and September for the year 2004 to 2006 respectively. From the values of the Releases by GA model from the table 1, it can be shown that every month of July, August, September and October, the demands are completely satisfied.

Table 1 is graphically represented below in Fig. 1.

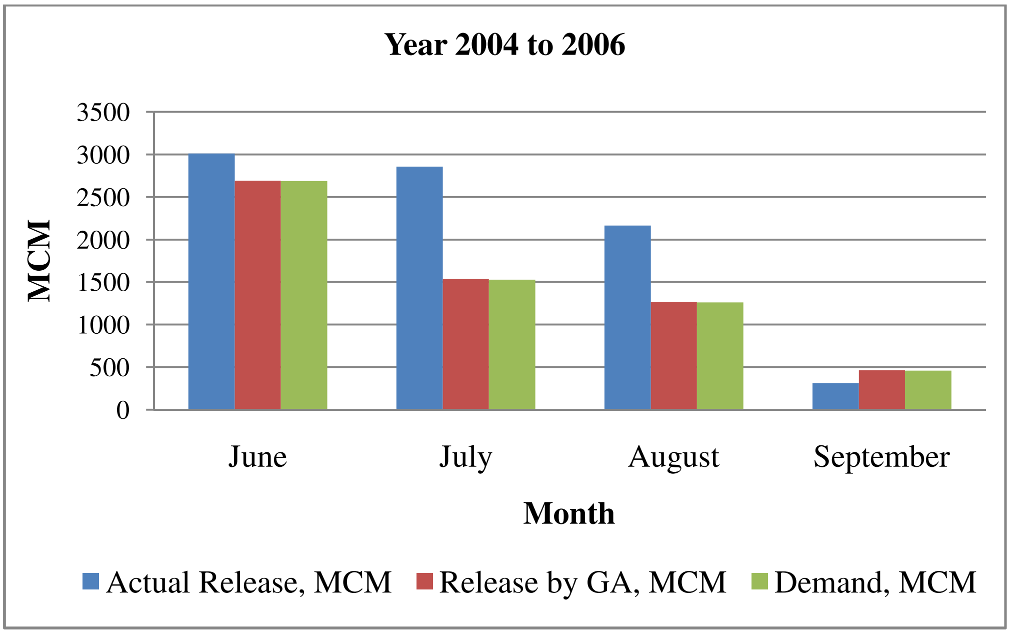

Fig.1 Actual Release, Release by GA and Demand for the year 2004 to 2006.

Fig.1 shows the Actual release, optimum release derived by genetic algorithm model and demand for every month of June, July, August and September respectively for the year 2004 to 2006. From Fig.1, it can be shown that in the month of June, July and August the releases achieved by GA model is less than the actual release and only in the month of September the reservoir release achieved by GA model is more than the actual release respectively but special care is taken to satisfy the demands. So, these derived releases for the month of June, July, August and September are the optimal releases. The amount and percentage of water that can be saved is shown in the Table 2.

Table 2: amount of water saved in MCM and in percentage for the year 2004 to 2006.

Month	June	July	August	September
Amount of Water saved, MCM	318.25	1319.6	897.78	-
Percentage of Water saved, %	10.57	46.20	41.49	-

Table 2 shows that the considerable amount of water that can be saved in MCM and in percentage for every month of June, July, August and September respectively for the year 2004 to 2006. In the month of June, July and August 318.25, 1319.6 and 897.78 MCM of water is saved respectively, which shows that 11 % of water is saved from the actual release in June, 46% in July and similarly 41 % in August. The (-) is show that the reservoir release obtained by GA is more than the actual release, so that water is not saved, but special care is taken to satisfy the downstream irrigation demands.

V. CONCLUSIONS

An optimal policy has been developed for release of water from the Sukhi reservoir project for the purpose of irrigation of crops. The releases obtained by Genetic algorithm satisfy completely the downstream irrigation demands for all the four months i.e. June, July, August and September from the year 2004 to 2006 respectively. The considerable amount of water saved in the months of June, July and August for year 2004 to 2006 is 318.25 MCM, 1319.6 MCM and 897.78 respectively. Thus, almost in nine out of twelve months the optimal releases obtained by genetic algorithm, are less than the actual releases, which leads to considerable amount in saving of water.

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